Chapter 4

Internet of Things (IoT)

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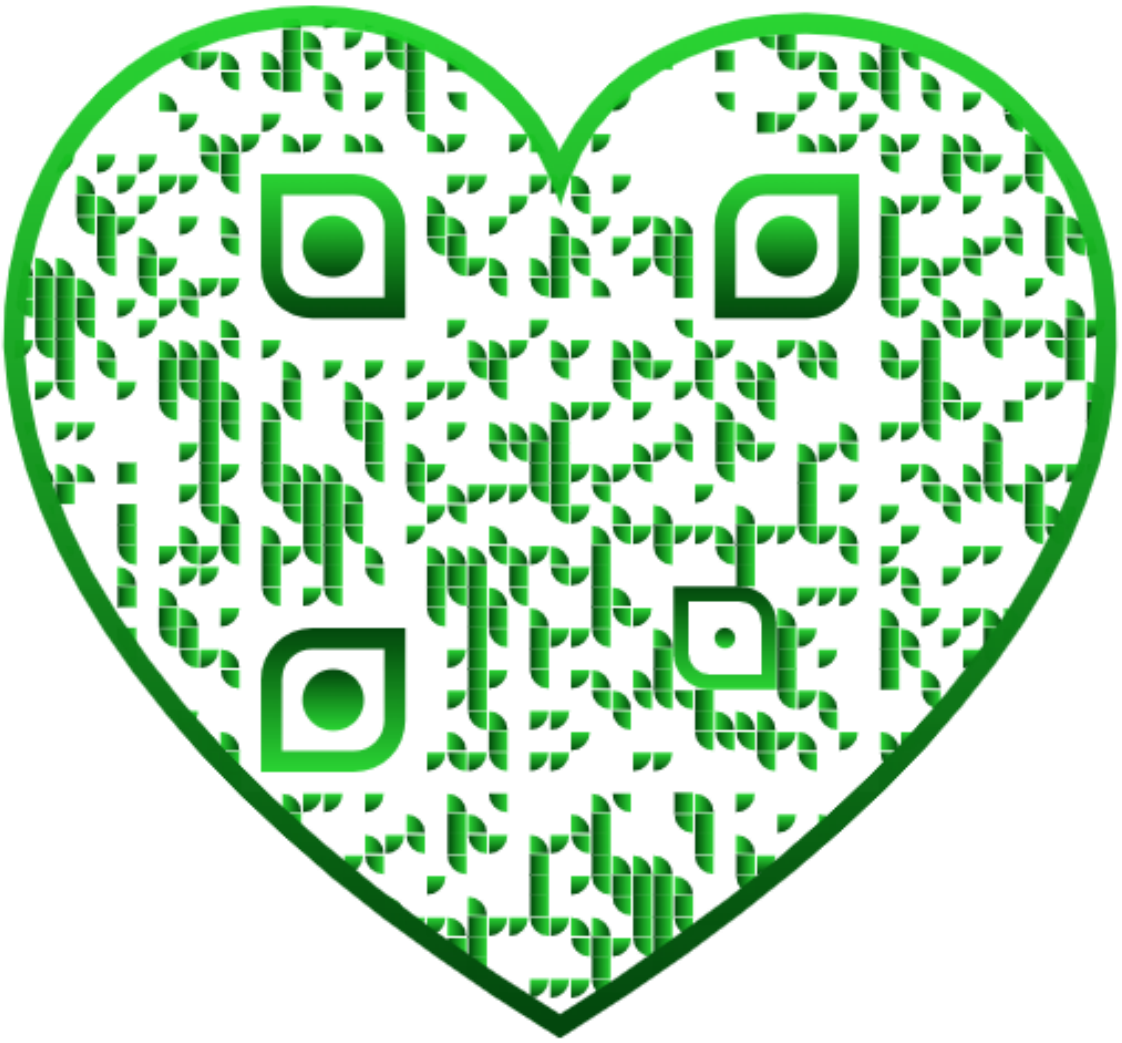


Objectives

At the end of this chapters students should understand:

- Overview and History of IoT
- Advantages of IoT
- Challenges of IoT
- How IoT works (Architectures, IoT Trends, Devices and Networks, Examples of IoT Applications, Management Platform for the Internet of Things)
- IoT Across Application Domains(Homes, Cities, healthcare, energy, Agriculture, transport …etc.)
- IoT Tools and Application Development Platforms
  - IoT Tools
  - IoT Platforms

THE INTERNET of THINGS

Overview of IoT

- The Internet of Things, or IoT, refers to the set of devices and systems that interconnect real-world **sensors and actuators** to the Internet.
- Internet of Things (IoT) is a network of devices which can sense, accumulate and transfer data over the internet without any human intervention.
- Internet of Things (IoT) is here to change the world we know.
- Smart cars, smart homes, smart cities, everything around us can be turned into a smart device with the help of Internet of Things
  - IoT surely brings the coolness factor to technology.

Overview of IoT

- A **sensor** is a device that detects and responds to some type of input (event) from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena
- An **actuator** is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". An **actuator** requires a control signal and a source of energy.

What is IoT Exactly?

Definitions from,

- **Internet Architecture Board (IAB):** The networking of smart objects (a huge number of devices intelligently communicating in the presence of internet protocol (IP) that cannot be directly operated by human beings but exist as components in buildings, vehicles or the environment).
- **Internet Engineering Task Force(IETF):** The networking of smart objects in which smart objects have some constraints such as limited bandwidth, power, and processing accessibility for achieving interoperability among smart objects

What is IoT Exactly?

Definitions from….

- **IEEE Communications**: A framework of all things that have a representation in the presence of the internet in such a way that new applications and services enable the interaction in the physical and virtual world in the form of Machine-to-Machine (M2M) communication in the cloud
- **Oxford dictionary:** The interaction of everyday object's computing devices through the Internet that enables the sending and receiving of useful data

Conceptual framework (2020) of IoT

- IoT= Services+ Data+ Networks + Sensors
- IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network **without requiring human-to-human or human-to-computer interaction**
- A **thing** in the internet of things can be a **person** with a heart monitor implant, a **farm animal with a biochip** transponder, an **automobile** that has built-in sensors to alert the driver when tire pressure is low, or any other **natural or man-made** objects that can be **assigned an IP address** and is able to **transfer data over a network**

Overview of IoT Cont'd...

- Internet of Thing s (IoT) is an ecosystem of connected physical objects that are accessible through the internet.
- According to the Gartner report, by **2020** connected devices across all technologies will reach **20.6 billion**.
- And by **2025**, we will have 41.6 billion connected **IoT devices**
- The number of IoT devices surpassed the global human population in 2010.

Types of IoT Systems

IoT includes many different systems, including

- Internet-connected cars
- wearable devices including health and fitness monitoring devices, watches, and even human implanted devices;
- smart meters and smart objects;
- home automation systems and lighting controls;
- smartphones that are increasingly being used to measure the world around them; and
- wireless sensor networks that measure weather, flood defenses, waves and more

IoT - Key technological enablers

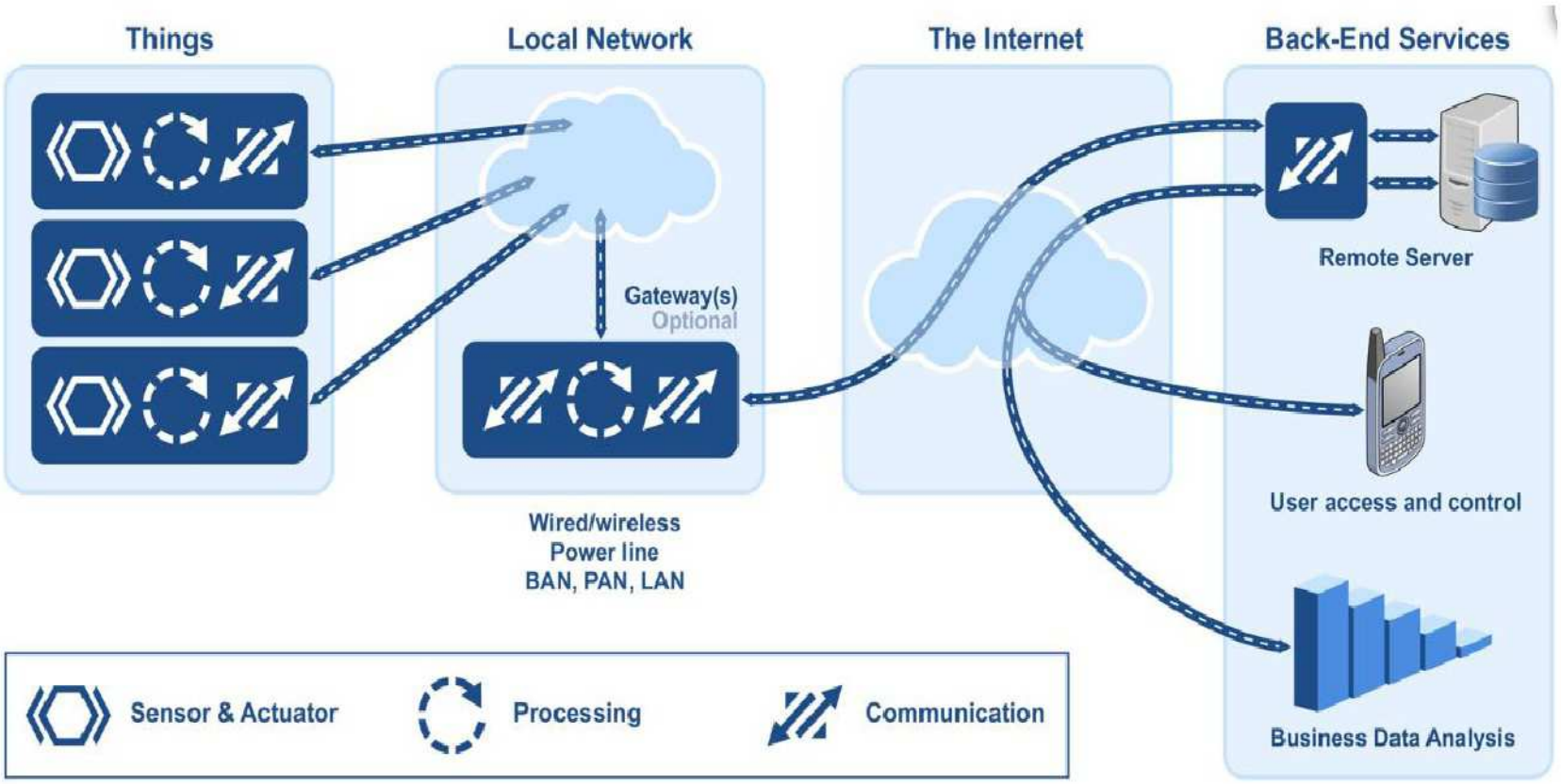
- The IoT four key technological **enablers** are: -
  - RFID (Radio-frequency identification) technology used for tagging the things.
  - Sensor technology used for sensing the things.
- Smart technology used for thinking the things.
- Nanotechnology used for shrinking the things.
- Generally speaking, IOT is just more than M2M communication, with technologies including:
- Wireless sensor networks, sensor networks , 2G/3G/4G,GSM,GPRS,RFID,WI-FI, GPS, microcontroller, microprocessor etc.

How to Think about the Internet of Things (IoT)

There are four main components of an IoT system

- The **Thing** itself (that is, the device)
- The **local network** (this can include a gateway, which translates proprietary communication protocols to Internet Protocol).
- The **Internet** (the Global Network)
- **Back-end services** (enterprise data systems, or PCs and mobile devices).

The Internet of Things from an embedded systems point of view



How to Think about the Internet of Things (IoT) Cont'd...

- There are, of course, two key aspects to the IoT:
- The devices themselves and
  - The server-side architecture that supports them.
- In fact, there is often a third-category that might be located between the device and the wider Internet
  - In many cases, there may be a low power gateway that performs
    - aggregation
    - event processing
    - bridging

Types of Devices (Things)

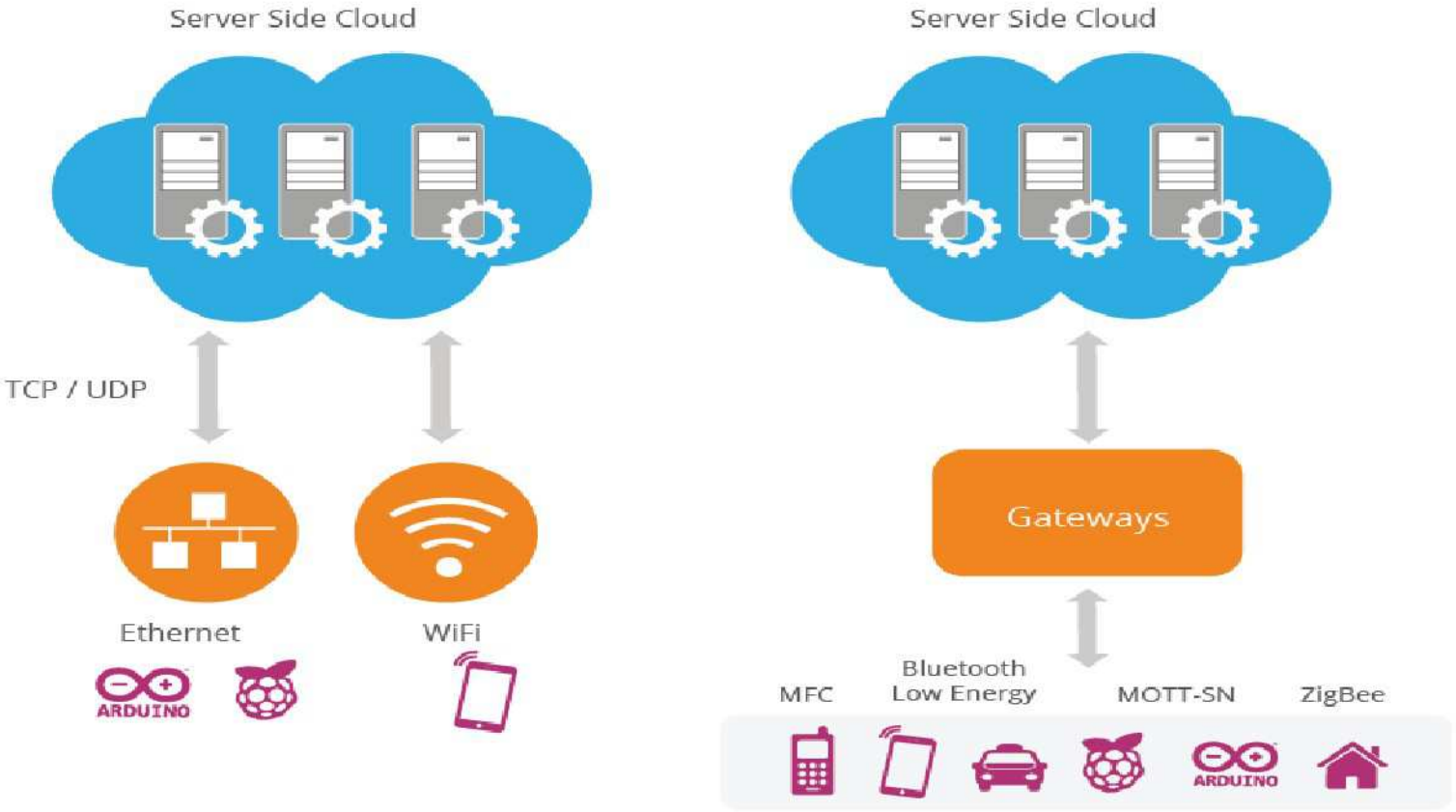
There are three types of Devices in IoT:

- **The smallest devices**
  - have embedded 8-bit System-On-Chip (SOC) controllers.
- **Small home routers and derivatives of those de**
  - Commonly, these run a cut-down or embedded Linux platform, such as OpenWRT, or dedicated embedded operating systems.
  - Have very limited 32 bit Atheros and ARM chips
- The **most capable IoT platforms that are full 32-b or 64-bit** computing platforms
  - Systems such as the Raspberry Pi or the BeagleBone, may run a full Linux OS or another suitable Operating System, such as Android.

IoT Communication Mechanisms

- Communication between devices and the Internet or to a gateway includes many different models
  - Direct Ethernet or Wi-Fi connectivity using TCP or UDP (we will look at protocols for this later)
  - Bluetooth Low Energy (BLE)
  - Near Field Communication (NFC)
  - Zigbee or other mesh radio networks
  - SRF and point-to-point radio links
  - UART or serial lines
  - SPI or I2C wired buses

The two major modes of connectivity (Communication)



History of IoT

- The term "The Internet of Things" (IoT) was coined by Kevin Ashton in a presentation to Proctor & Gamble in 1999.
- He is a co-founder of MIT's Auto-ID Lab.
- He pioneered RFID (used in bar code detector) for the supply-chain management domain.

History of IoT Cont'd...

- Although Ashton was the first man to mention of the "internet of things", the idea of connected devices has been around since the1970s, under the monikers embedded internet and pervasive computing.
- The first internet appliance, for example, was a Coke vending machine at Carnegie Mellon University in the early 1980s.
  - Using the web, programmers could check the status of the machine and determine whether there would be a cold drink awaiting them, should they decide to make the trip to the machine.

Evolution of the Internet

- **Pre-Internet**
  - In the pre-internet era, most of the human to human communication was through fixed line and mobile telephony.
- **Dawn of Internet**
  - With the origin of Internet, the world changed at once. We could be continents apart and still share vital information at just the click of a button.

Evolution of the Internet Cont'd...

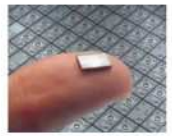
- **Internet of People**
  - After the invention of blogging, social media began to explode in popularity.
  - Sites like MySpace, Facebook, and LinkedIn gained prominence in the early 2000s.
  - YouTube came out in 2005, creating an entirely new way for people to communicate and share with each other across great distances.

Evolution of the Internet Cont'd...

- **Internet of Things**
  - Nearly all of the data available on the Internet today was first captured and created by **human beings.**
  - The problem is, people have limited time, attention, and accuracy, which means they are not very good at capturing data about things in the real world.
  - So, if we had computers that knew everything there was to know about things, using data they gathered without any help from us, we would be able to track and count everything and greatly reduce waste, loss and cost
  - This is what gave birth to "**Internet of Things**".

History of IoT Cont'd...

- IoT has evolved from the convergence of
- wireless technologies,
  - microelectromechanical systems (MEMS),
  - microservices and
  - the Internet.



- The convergence has helped tear down the silos(Free-Flow of Information) between operational technology (OT) and information technology (IT),

History of IoT Cont'd...

- This convergence enabled unstructured machine-generated data to be analyzed for insights to drive improvements.
- IoT evolved from machine-to-machine (M2M) communication,
  - i.e., machines connecting to each other via a network without human interaction.
  - M2M refers to connecting a device to the cloud, managing it and collecting data.

History of IoT Cont'd...

- Machine-type communication (MTC), also known as machine-to-machine communication (M2M), describes any network where two or more devices exchange data directly and without user intervention.
- Taking M2M to the next level, IoT is a sensor network of billions of smart devices that connect people, systems and other applications to collect and share data.
- As its foundation, M2M offers the connectivity that enables IoT.

Why is IoT important?

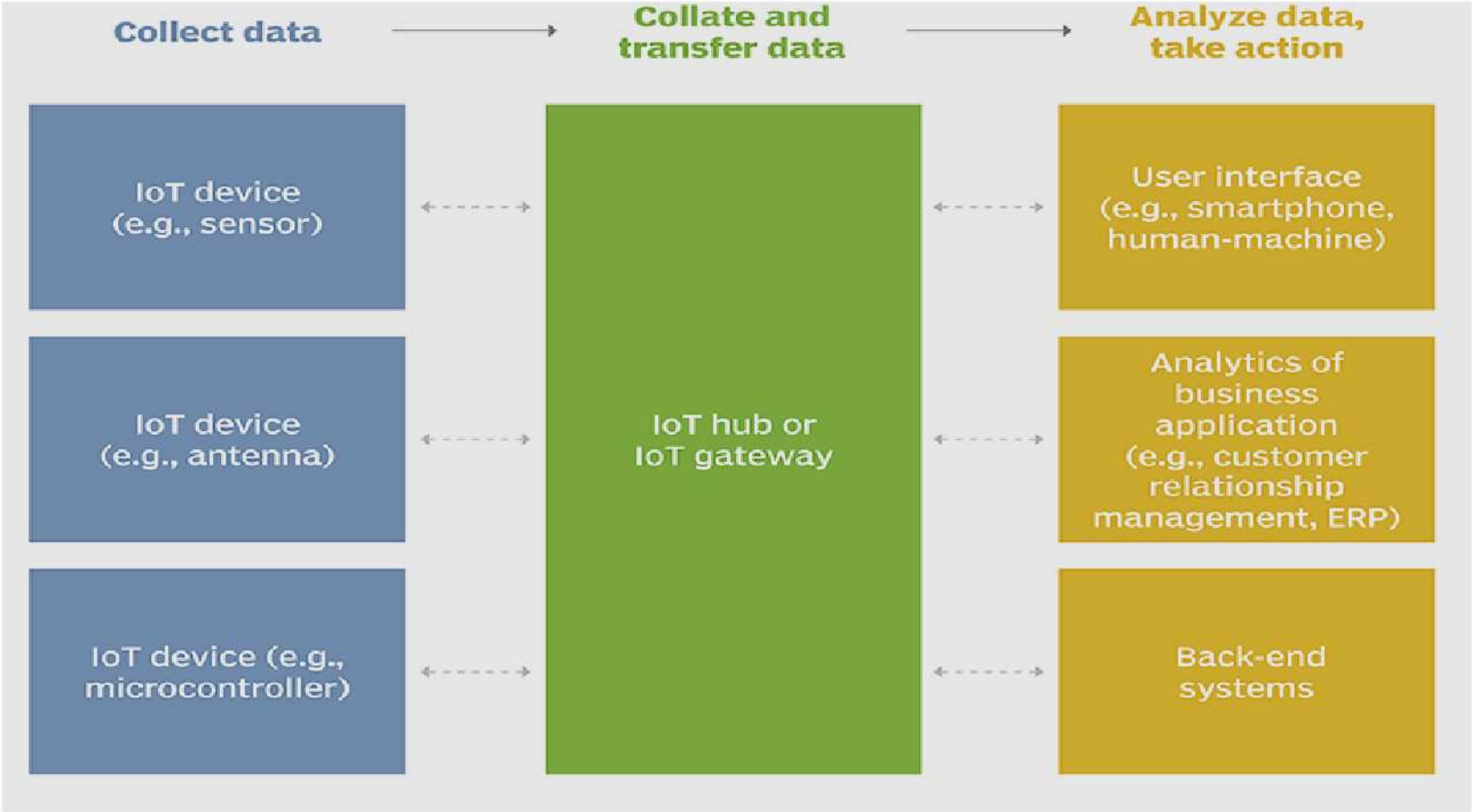
- Touches every industry, including healthcare, finance, retail, and manufacturing
  - Helps people live and work smarter
    - Smart homes, smart, cities, smart kitchen…
      - Smart cities help citizens reduce waste and energy consumption
  - Provides businesses with a real-time look into how their companies' systems really work
    - Delivering insights into everything from the performance of machines to supply chain and logistics operations
    - Connected sensors are even used in farming to help monitor crop and cattle yields and predict growth patterns

SMART HOME
FIRST FLOOR
LOCK
GARAGE

Why is IoT important?

- Touches every industry….Cont'd…
  - Enables companies to automate processes and reduce labor costs
  - Cuts down on waste and improves service delivery
    - Less expensive to manufacture and deliver goods as well as offering transparency into customer transactions

Example of an IoT System


Collect data
Collate and transfer data
Analyze data, take action
IoT device (e.g., sensor)
IoT device (e.g., antenna)
IoT device (e.g., microcontroller)
IoT hub or IoT gateway
User interface (e.g., smartphone, human-machine)
Analytics of business application (e.g., customer relationship management, ERP)
Back-end systems

Pros and cons of IoT

Advantage

- **Improved (active) Customer Engagement**
- **Technology Optimization**
- **Reduced Waste**
- **Enhanced Data Collection(sensors do that)**

Disadvantages

- **Increased Security Concern**(s more devices and more info created and shared, hacker could steal confidential information)
- **Big Data Management** issue **(**managing the data from all those devices will be challenging)
- **The higher chance of system corruption (**if there is a bug in any part of the system**)**
- **Device Interoperability(** multiple, different device vendors with no accepted standard**)**

Key IoT Challenges

- There are key challenges and implications today that need to be addressed before the mass adoption of IoT can occur that include:
  - **Privacy and Security** (refer to the security issues at different Layers of IOT)
    - Trust and quality of-information in shared information models
    - Secure exchange of data between IoT devices and consumers of their information
    - Protection mechanisms for vulnerable devices

Key IoT Challenges

- **Cost versus Usability** - reduction in cost of devices and mechanism to use devices is expected
- **Interoperability**
  - With numerous sources of data and heterogeneous devices, the use of standard interfaces between these diverse entities becomes important
- **Data Management**
  - the volume of the generated data and the processes involved in the handling of those data become critical
- **Device Energy Consumption Level**
  - How to interconnect "things" in an interoperable way while taking into account the energy constraints
    - Communication between devices takes the most energy

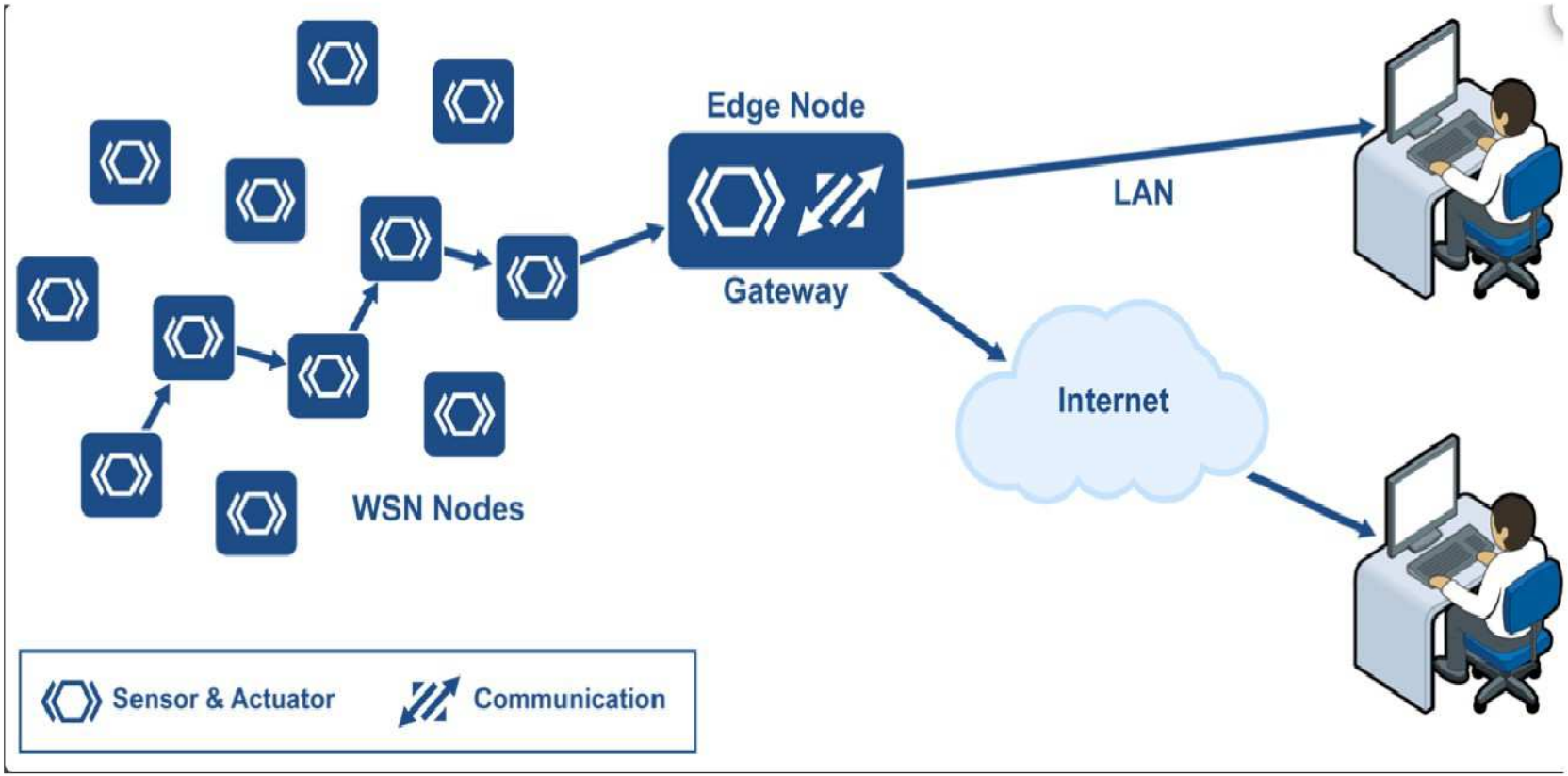
How IoT Works

- An IoT ecosystem consists of web-enabled smart devices that use
  - embedded processors
  - sensors and
  - communication hardware

  to collect, send and act on data they acquire from their environments.
- IoT devices share the sensor data they collect by connecting to
  - an IoT **gateway** or
  - another **edge device**

  where data is either sent to the cloud to be **analyzed** or **analyzed locally**.
- **Sometimes**, these devices communicate with other related devices and act on the information they get from one another

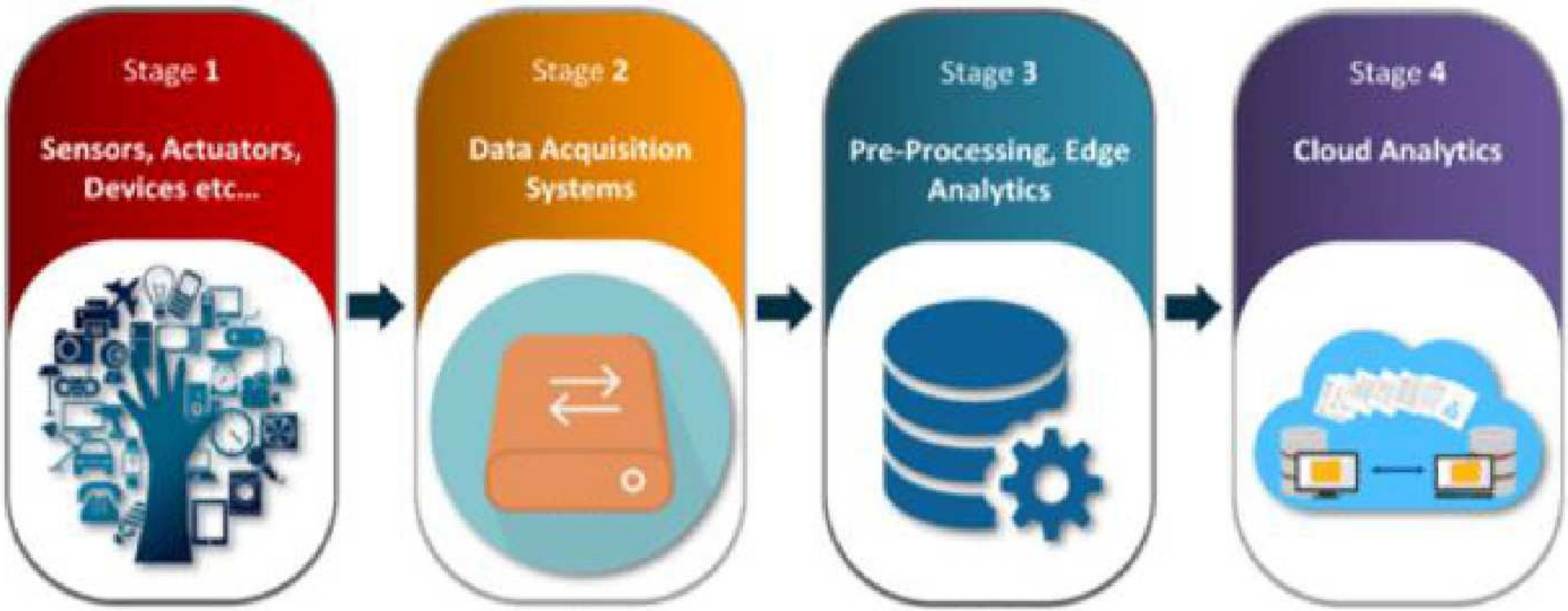
Wireless sensor network installed in a factory, connected to the Internet via a gateway



How IoT Works

- Remember that;
  - IoT is the technology that builds systems capable of autonomously sensing and responding to stimuli from the real world without human intervention
- We, therefore, need to develop a process flow for a definite framework over which an IoT solution is built.
  - The IoT Architecture (to be discussed shortly) is generally comprised of 4 stages

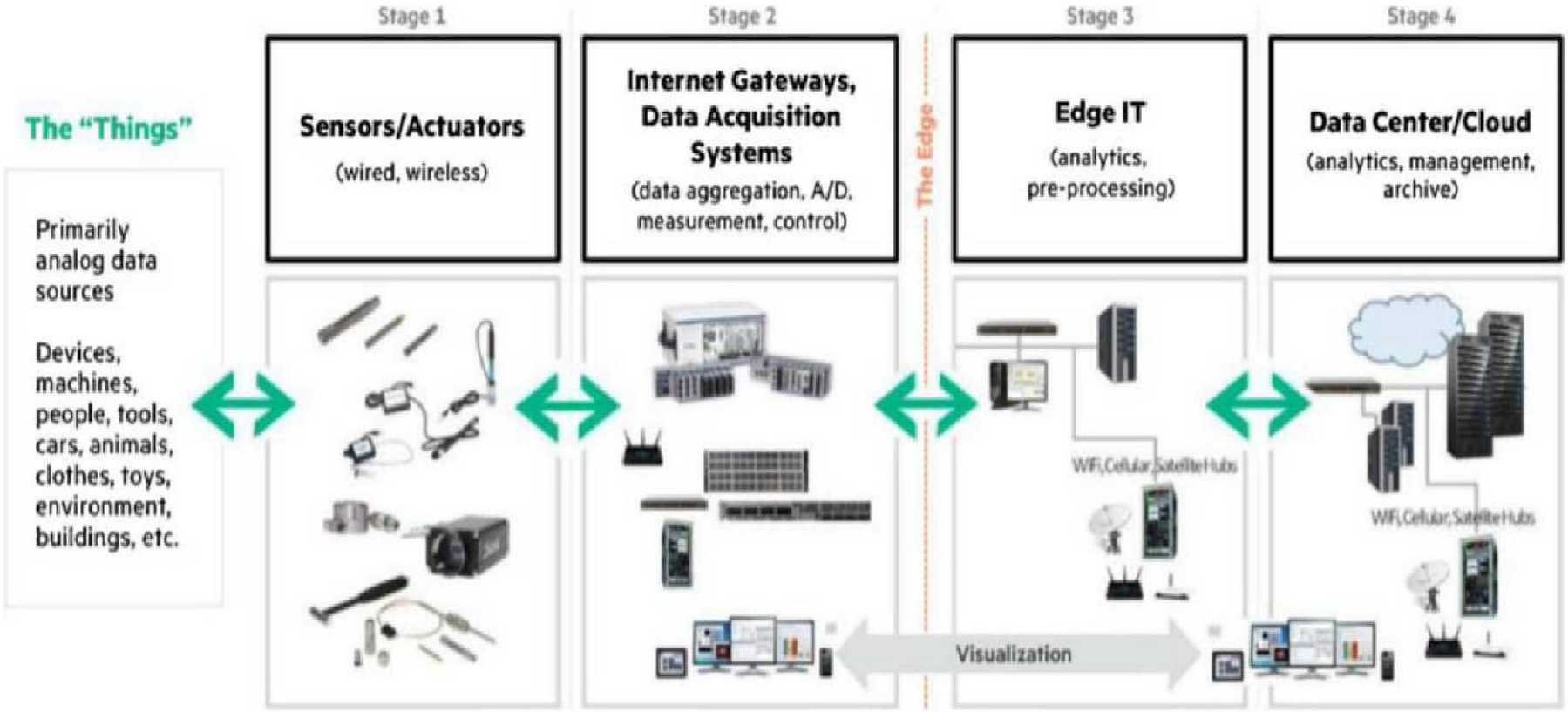
How IoT Works Cont'd...



How IoT Works - the 4 stages

- **Stage 1 (Sensors/Actuators)**
  - A thing in the context of "Internet of Things", should be equipped with sensors and actuators thus giving the ability to emit, accept and process signals
- **Stage 2 (Data Acquisition Systems):**
  - The data from the sensors starts in analogue form which needs to be aggregated and converted into digital streams for further processing.
    - This stage performs these data aggregation and conversion functions
- **Stage 3 (Edge Analytics)**
  - Once IoT data has been digitized and aggregated, it may require further processing before it enters the data center, this is where Edge Analytics comes in
- **Stage 4 (Cloud Analytics)**
  - Data that needs more in-depth processing gets forwarded to physical data centers or cloud-based systems.

How IoT Works - the 4 stages



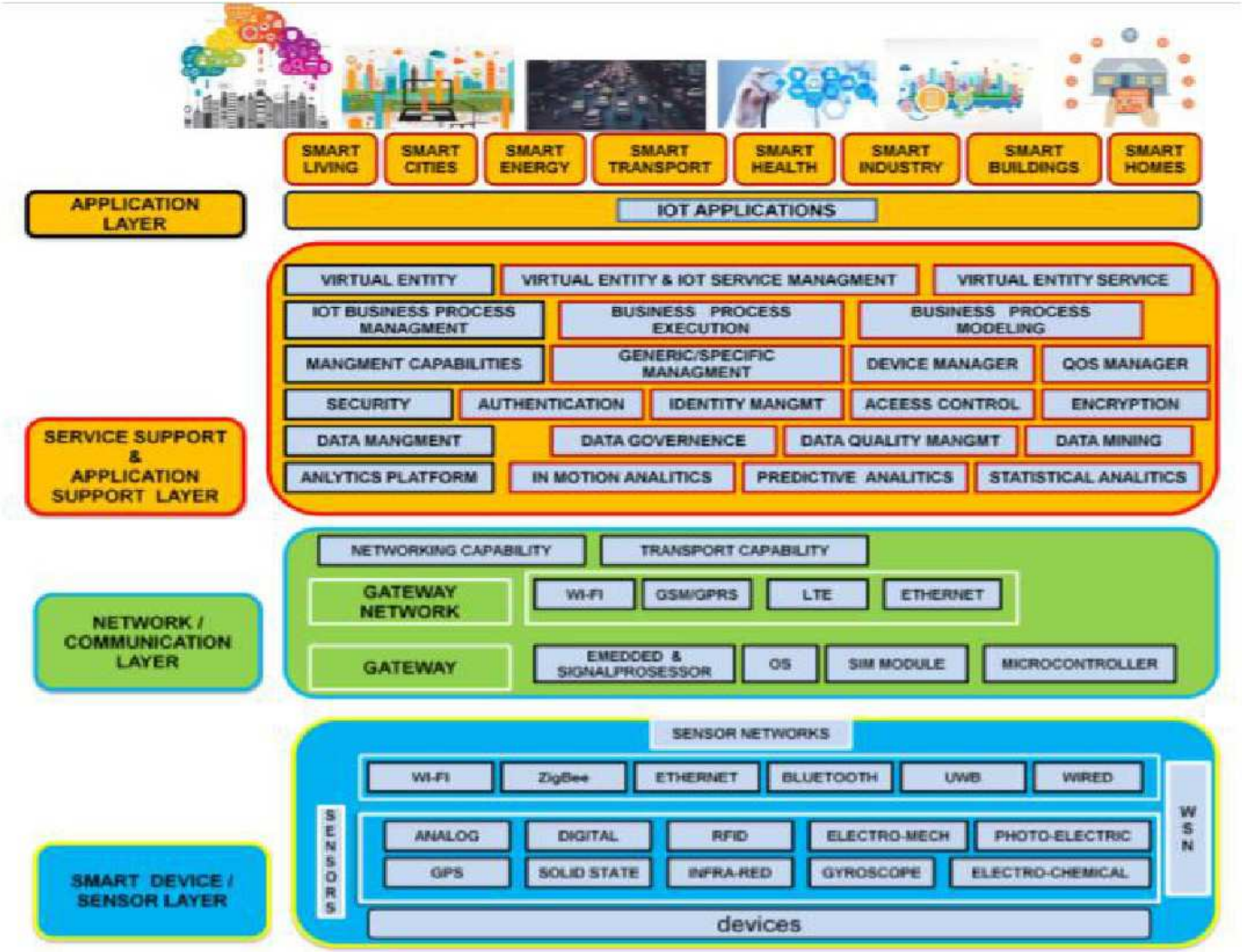
IoT Architecture

- Most researchers agree on a **conventional architecture** for IoT that includes the following layers
  - Perception Layer
  - Network Layer
  - Application Layer
- Some other latest variants, as included in IoT's latest architecture, add a **support layer** that lies between the application layer and network layer
  - Support layer consists fog computing and cloud computing

IoT Architecture

- Hence, IOT architecture consists of different layers of technologies supporting IOT.
- It serves to illustrate how various technologies relate to each other and to communicate the scalability, modularity and configuration of IOT deployments in different scenarios.
- The latest agreed upon IoT Architecture is composed of
- Smart device / sensor layer (Perception)
  - Gateways and Networks Layer
  - Management Service Layer
  - Application Layer

IoT Layered Architecture



IoT Layered Architecture - descriptions

- Smart device / sensor layer
  - Lowest layer, made up of smart objects integrated with sensors,
  - The sensors enable the interconnection of the physical and digital worlds allowing real-time information to be collected and processed
  - Various types of sensors for different purposes
    - sensors have the capacity to take measurements such as temperature, air quality, speed, humidity, pressure, flow, movement and electricity etc.

IoT- Architecture : Smart device / sensor layer

Here is a list of some of the measurement devices used in IoT:

- accelerometers
- temperature sensors
- magnetometers
- proximity sensors
- gyroscopes
- image sensors
- acoustic sensors
- light sensors
- pressure sensors
- gas RFID sensors
- humidity sensors
- microflow sensors

IoT- Architecture : Smart device / sensor layer cont'd...

- Most sensors require connectivity to the sensor gateways.
- This can be in the form of a Local Area Network (LAN) such as Ethernet and Wi-Fi connections or Personal Area Network (PAN) such as ZigBee, Bluetooth and Ultra Wideband (UWB).
- For sensors that do not require connectivity to sensor aggregators, their connectivity to backend servers/applications can be provided using Wide Area Network (WAN) such as
  - GSM, GPRS and LTE.
- Sensors that use low power and low data rate connectivity typically form networks commonly known as wireless sensor networks (**WSNs**)

IoT- Architecture : Gateways and Networks Layer

- Massive volume of data will be produced by these tiny sensors and this requires a **robust and high performance wired or wireless network infrastructure** as a transport medium.
- Current networks(IP based), often tied with very different protocols, have been used to support machine-to-machine (M2M) networks and their applications.
- With demand needed to serve a wider range of IOT services and applications such as
  - high speed transactional services,
  - context-aware applications

, multiple networks with various technologies and access protocols are needed to work with each other in a heterogeneous configuration.

IoT- Architecture : Gateways and Networks Layer

- Any protocol that **carries IP packets has an advantage over all others.**
- The connectivity requirements for IoT devices are so diverse that a single technology cannot meet all the range, power, size and cost requirements.
- The importance of IP to the Internet of Things does not automatically mean that non-IP networks are useless.
  - It just means that non-IP networks require a gateway to reach the Internet.

IoT- Architecture : Gateways and Networks Cont'd...

- These networks can be in the form of a private, public or hybrid models and are built to support the communication requirements for latency, bandwidth or security.
- Various **gateways** (microcontroller, microprocessor…) & **gateway networks** (WI-FI, GSM, GPRS…)
- A smart IoT gateway is implemented to provide data processing, local web server, and cloud connection.
- After the **gateway** receives the data from wearable sensors, **it will forward the data to an IoT cloud for further da storage, processing and visualization**.

IoT- Architecture : Gateways and Networks Cont'd...

- This layer also ensures **unique addressing** and routing abilities to the unified integration of uncountable devices in a single cooperative network.
  - Various types of technologies have contributed to this phenomenon such as wired, wireless and satellite technologies.
  - The implementation of 6LoWPAN(Low Power Personal Area Network over IP version 6) protocol towards IPV6 for unique addressing of devices was also important development.
  - **IPv6 is Key for IoT**
    - IPv6's addressing scheme provides more addresses than there are grains of sand on earth

IoT- Architecture : Management Service Layer

- The management service renders the processing of information possible through
  - Analytics,
  - Security controls,
  - Process modeling and
  - Management of devices
- Services may include **application and support** services)
  - Often provided by cloud/ fog computing technologies

IoT- Architecture : Management Service Cont'd...

- Management Service Layer- Features
  - **Business and process rule engines**
    - Support the formulation of decision logic and trigger interactive and automated processes to enable a more responsive IOT system
  - **Analytics**
    - Various analytics tools are used to extract relevant information from a massive amount of raw data and to be processed at a much faster rate
      - Two types
        - **In-memory analytics:** allows large volumes of data to be cached in random access memory (RAM) rather than stored in physical disks
        - **Streaming analytics**: allows analysis of data, considered as data-in-motion, is required to be carried out in real-time so that decisions can be made in a matter of seconds

IoT- Architecture : Management Service Cont'd...

- Management Service Features
  - **Data management** is ability to manage data information flow
    - With data management in the management service layer, information can be accessed, integrated and controlled.
    - Data filtering techniques such as
      - data anonymization,
      - data integration, and
      - data synchronization,

    are used to hide the details of the information while providing only essential information that is usable for the relevant applications

IoT- Architecture : Management Service Cont'd...

- Management Service Features
- **Security**
  - Must be enforced across the whole dimension of the IoT architecture right from the smart object layer all the way to the application layer.
  - Security of the system prevents system hacking and compromises by unauthorized personnel, thus reducing the possibility of risks.

IoT- Architecture : Application Layer

Application covers "smart" environments/spaces in domains such as:

- Transportation,
- Building,
- City,
- Lifestyle,
- Retail,
- Agriculture,
- Factory,
- Supply chain,
- Emergency,
- Healthcare,
- User interaction,
- Culture and tourism,
- Environment and Energy.

IoT- Trend, Devices and Networks

- **IoT Trends**: Since 2010, industry leaders have been predicting an explosion in the number of connected devices.
  - Different estimates of IoT devices to be connected to the Internet
    - By 2020, Gartner 20.6 billion , CISCO 50 Billion….
    - By 2025 41.6 Billion etc.…
  - A wide range of fields that have been adopting IoT infrastructures includes connected and smart cities, manufacturing, energy and utilities, transport, logistics and even agriculture
    - i.e. IoT is being adopted in many areas of applications
  - IoT has no practical limit as to the number of devices deployed
    - IPv6…
  - However, the number of IoT devices is only limited by the scope of the applications themselves

IoT- Trend, Devices and Networks Cont'd...

- **IoT Devices**
  - A wireless sensor network (**WSN**) is a collection of distributed sensors that monitor physical or environmental conditions, such as temperature, sound, and pressure.
  - Data from each sensor passes through the network, node-to-node
  - **WSN Nodes -** are low-cost devices, so they can be deployed in high volume.
    - They also operate at low power so that they can run on battery, or even use energy harvesting.
    - A WSN node is an embedded system that typically performs a single function (such as measuring temperature or pressure or turning on a light or a motor).
    - Energy harvesting is a new technology that derives energy from external sources (for example, solar power, thermal energy, wind energy, electromagnetic radiation, kinetic energy, and more).

IoT- Trend, Devices and Networks Cont'd...

- **IoT Devices Cont'd...**
  - **WSN Edge Nodes**
    - A WSN edge node is a WSN node that includes **Internet Protocol** connectivity.
    - It acts as a **gateway** between the WSN and the IP network
    - It offers local processing, provide local storage, and feature a user interface
- **IoT Devices Cont'd....**
  - The battle over the preferred networking protocol is far from over. There are multiple candidates
    - Wi-Fi
    - IEEE 802.15.4
    - 6LoWPAN
    - Bluetooth

IoT- Trend, Devices and Networks-Cont'd...
Wireless radio technologies comparison

Standard	IEE 802.15.4	Bluetooth	Wi-Fi
Frequency	868/915 MHZ, 2.4 GHz	2.4 GHz	2.4, 5.8 GHz
Data rate	250 Kpbs	723 Kpbs	11 to 105 Mpbs
Data rate	250 Kpbs	723 Kpbs	11 to 105 Mpbs
Power	Very Low	Low	High
Battery Operation	Alkaline (months to years)	Rechargeable (days to weeks)	Rechargeable (hours)

IoT- Trend, Devices and Networks Cont'd...

- **IoT Networks**
  - As the amount of IoT devices grows, the underlying telecommunications networks that support and serve them must also adapt.
  - Telecommunication infrastructures must be designed to accommodate the traffic they carry.
  - Voice, video, and data have particular characteristics and requirements for successful transmission over the network.
  - IoT traffic **differs significantly in its nature** and thus has unique network requirements that must be taken into account when designing the network that will carry them

IoT- Trend, Devices and Networks Cont'd...

- **IoT Networks Cont'd…**
  - An IoT network typically includes a number of devices with constrained resources (**power, processing, memory, among others**)
  - Some of those devices may be massively deployed over large areas like smart cities, industrial plants,
  - Whereas others may be deployed in **hard-to-reach areas like pipelines hazardous zones, or even in hostile environments** like war zones.
  - Therefore, the efficient management of IoT networks requires considering both the constraints of low power IoT devices and the deployment complexity of the underlying communication infrastructure.

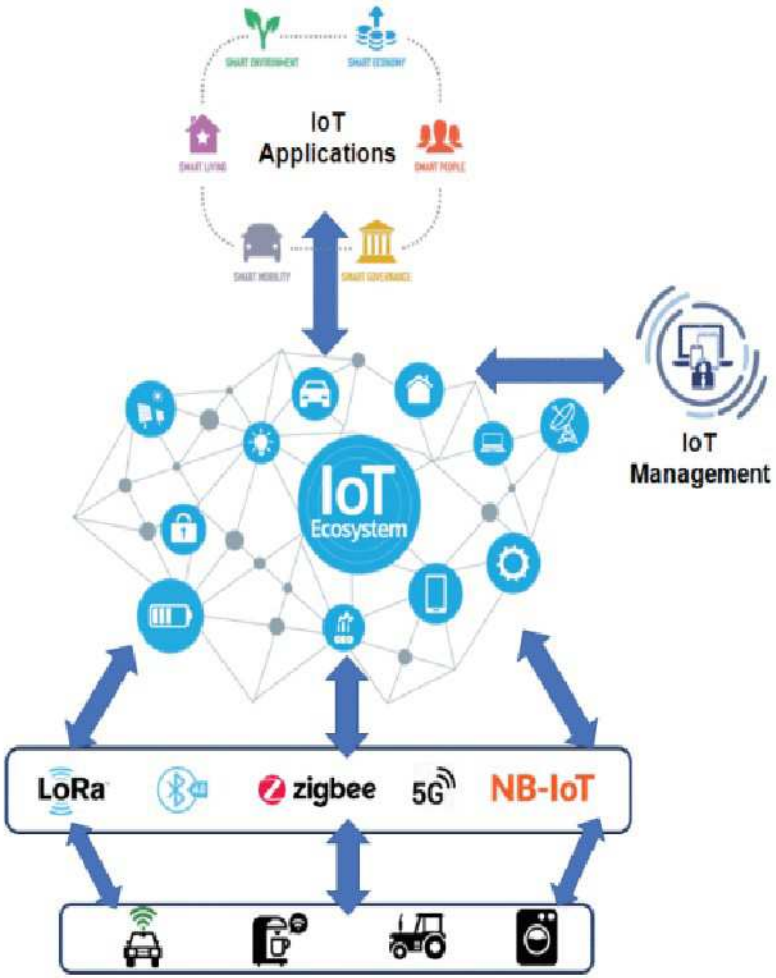
IoT- Trend, Devices and Networks Cont'd...

- IoT network requirements
  - The ability to connect large numbers of heterogeneous IoT elements
  - High reliability
  - Real-time awareness with low latency
  - Ability to secure all traffic flows
  - Programmability for application customization
  - Traffic monitoring and management at the device level
  - Low-cost connectivity for a large number of devices/sensors

Networks and Devices Management Platform for the Internet of Things

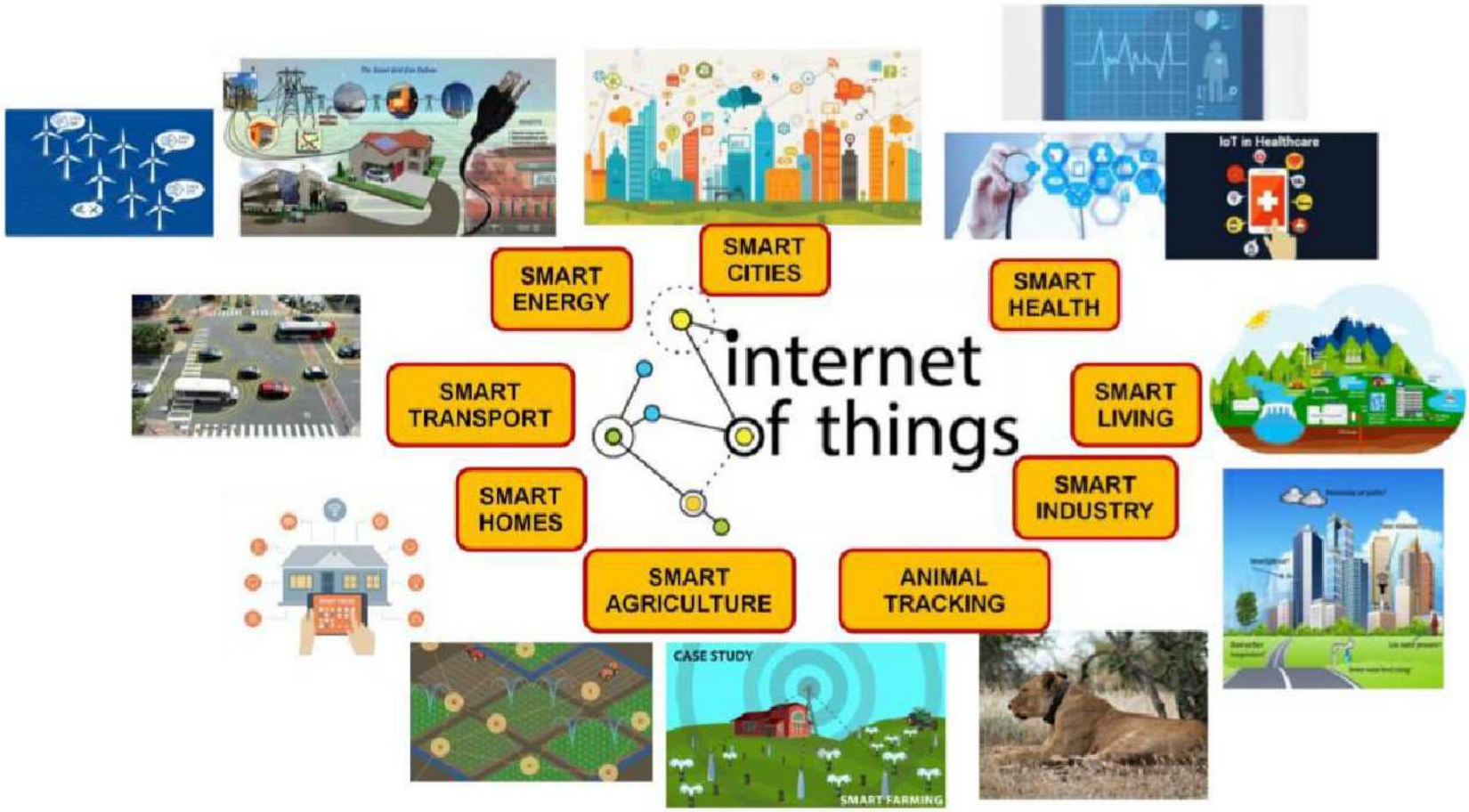
- To ensure the correct functioning of those connected devices, they must be remotely accessed to configure, monitoring their status, and so forth.
- Traditional management solutions cannot be used for low power devices networks given their resources limitation and scalability issues.
- Therefore, efficient and autonomic management of IoT networks is needed

Illustration of an IoT scenario



- A simplified representation of an IoT network. Itencompasses end devices, gateways, communication links, IoT applications, and services.
- A typical scenario involving those entities include end devices collecting data from an environment(e.g., temperature, luminosity, movement) and reporting it to a supervision entity (hosted by an IoT platform and service provider) via different communication technologies and gateways.
- Must have a means to device provisioning, administration, monitoring, and diagnostics important for trouble replication and corrective measures.
- An Ideal solution will provide a means for managing all devices **from one dashboard**.

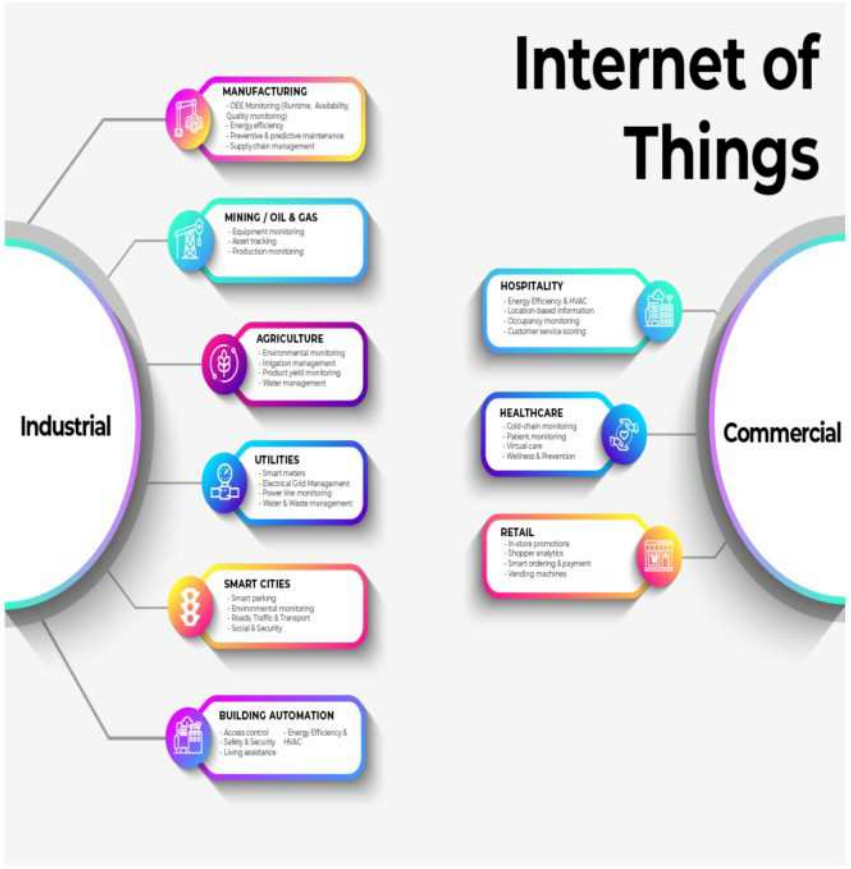
IoT Across Application Domains



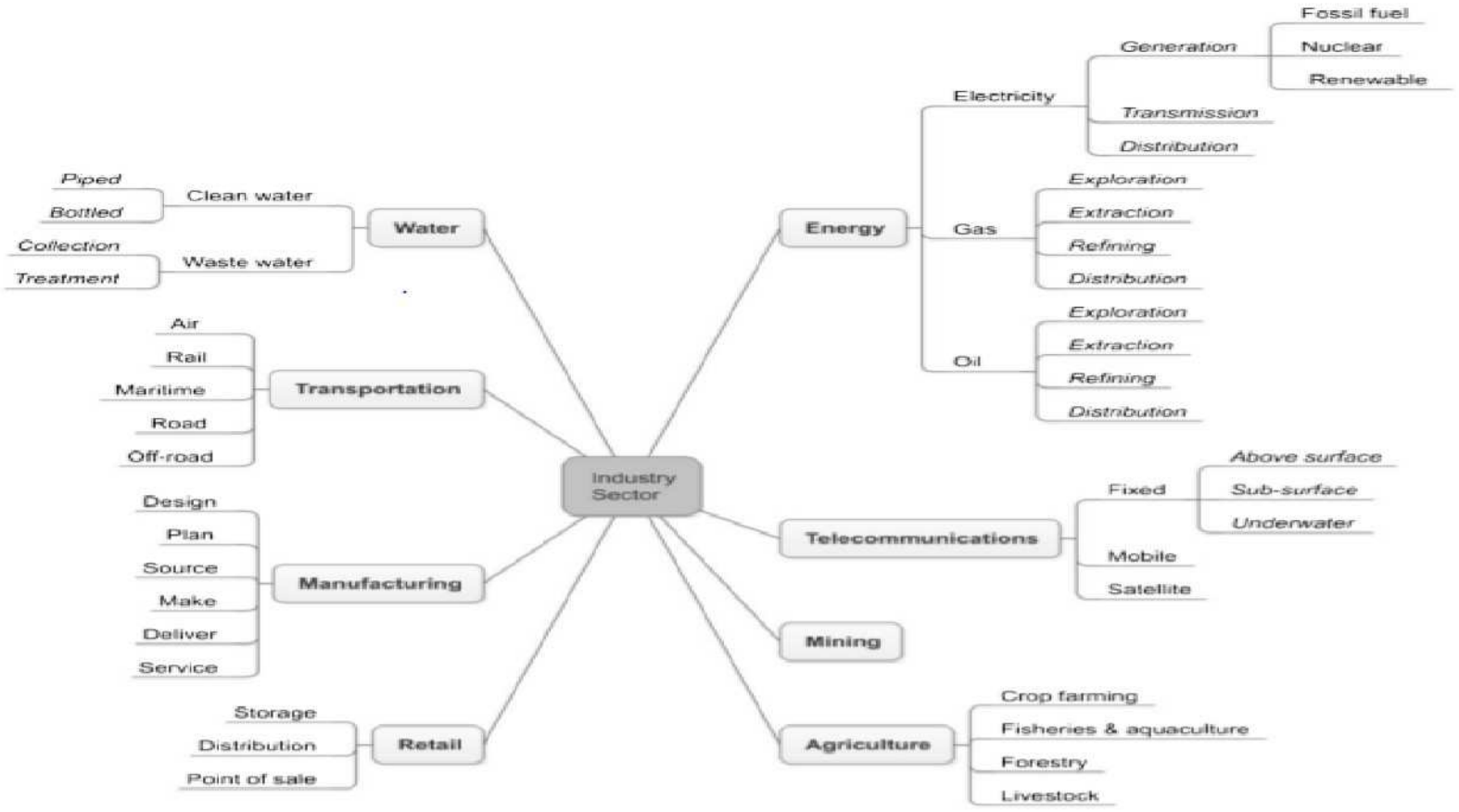
IoT Across Application Domains

- There are numerous real-world applications of the internet of things, ranging from:
  - Consumer IoT and Enterprise IoT to
  - Manufacturing and Industrial IoT (IIoT).

Consumer IoT, Industrial IoT, Commercial IoT and Enterprise IoT



IoT Across Application Domains -13 application domains have taken up IOT



IoT Applications - Smart Homes

- For consumers, the connectivity provided by the IoT could enhance their quality of life in multiple ways, such as, but not limited to, energy efficiency and security at home and in the city.
- Connected smart devices will enable a reduction in **utility bills and outages**, while also improving home security via **remote home monitoring.**
- Smart Home has become a reality **where all devices are integrated and interconnected via the wireless network**.
  - These "smart" devices have the potential to share information with each other.

IoT Applications - Smart Homes

- Smart Home Appliances:
  - **Remote Control Appliances:** Switching on and off remotely appliances to avoid accidents and save energy
  - **Refrigerators** with LCD screen telling what's inside, food that's about to expire, ingredients you need to buy and with all the information available on a smartphone app.
  - **Washing machines** allowing you to monitor the laundry remotely, and.
  - **Kitchen** ranges with interface to a Smartphone app allowing remotely adjustable temperature control and monitoring the oven's self-cleaning feature,
  - **Safety Monitoring**: cameras, and home alarm systems making people feel safe in their daily life at home,
  - **Intrusion Detection Systems**: Detection of window and door openings and violations to prevent intruders
  - **Weather**: Displays outdoor weather conditions such as humidity, temperature, pressure, wind speed and rain levels with ability to transmit data over long distances
  - **Energy and Water Use**: Energy and water supply consumption monitoring to obtain advice on how to save cost and resources

IoT Across Application - Smart Energy Applications

- Energy Applications
  - IoT provides a way to not only monitor the energy usage at the appliance-level but also at the house-level, grid level or could be at the distribution level.
  - Smart Meters & Smart Grid are used to monitor energy consumption.
- With smart grids energy distribution can be optimized.
- These grids also keep collecting real-time data which helps in distributing electricity efficiently and also to reduce the outages.

IoT Across Application - Smart City Applications

- **Lighting** : intelligent and weather adaptive lighting in street lights.
- **Smart Roads** and **Intelligent High-ways** with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams
- **Smart Parking**: Real-time monitoring of parking spaces availability in the city making residents able to identify and reserve the closest available spaces
- **Waste Management**: Detection of rubbish levels in containers to optimize the trash collection routes.
  - Garbage cans and recycle bins with RFID tags allow the sanitation staff to see when garbage has been put out

IoT Across Application - Smart City Applications

- In Smart Cities, the development of smart grids, data analytics, and autonomous vehicles will provide an intelligent platform to deliver innovations in
  - Energy management,
  - Traffic management, and
  - Security,

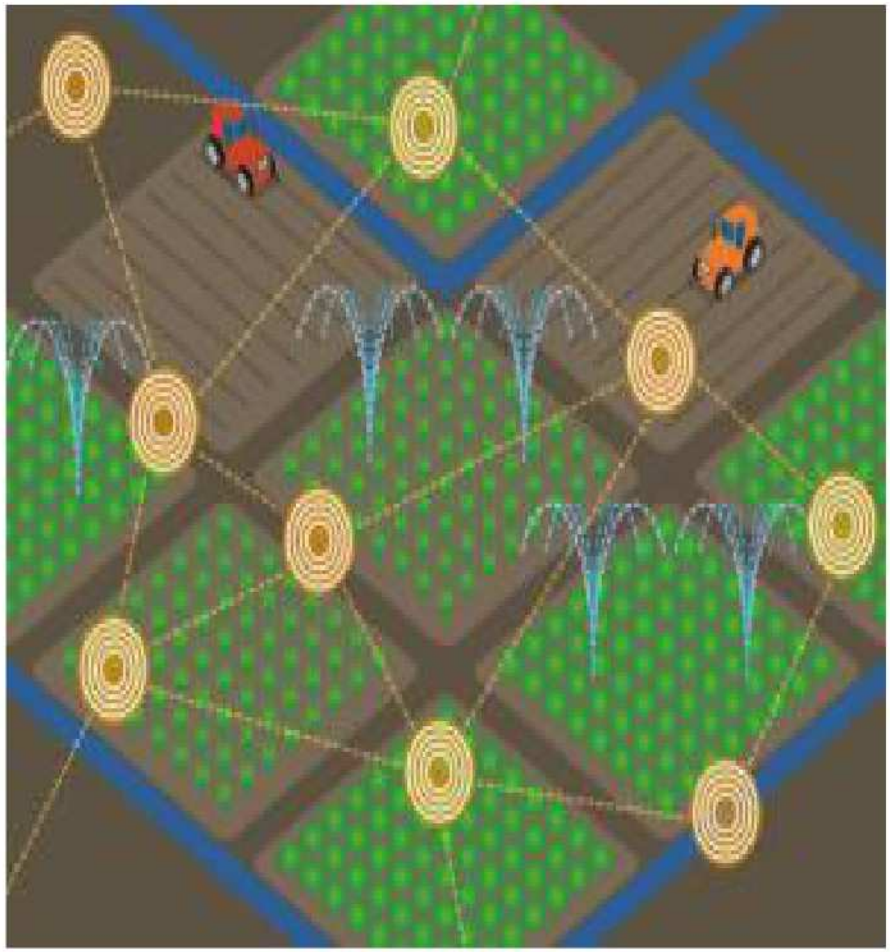
  by sharing the benefits of this technology throughout society

IoT- in Agriculture - Smart Agriculture

- Green Houses: Control micro-climate conditions to maximize the production of fruits and vegetables and its quality,
- Compost: Control of humidity and temperature levels in alfalfa, hay, straw, etc. to prevent fungus and other microbial contaminants,
- Animal Farming/Tracking: Location and identification of animals grazing in open pastures or location in big stables, Study of ventilation and air quality in farms and detection of harmful gases from excrements,
- Offspring Care: Control of growing conditions of the offspring in animal farms to ensure its survival and health,
- Field Monitoring: Reducing spoilage and crop waste with better monitoring, accurate ongoing data obtaining, and management of the agriculture fields, including better control of fertilizing, electricity and watering

IoT-in Agriculture - Smart Agriculture

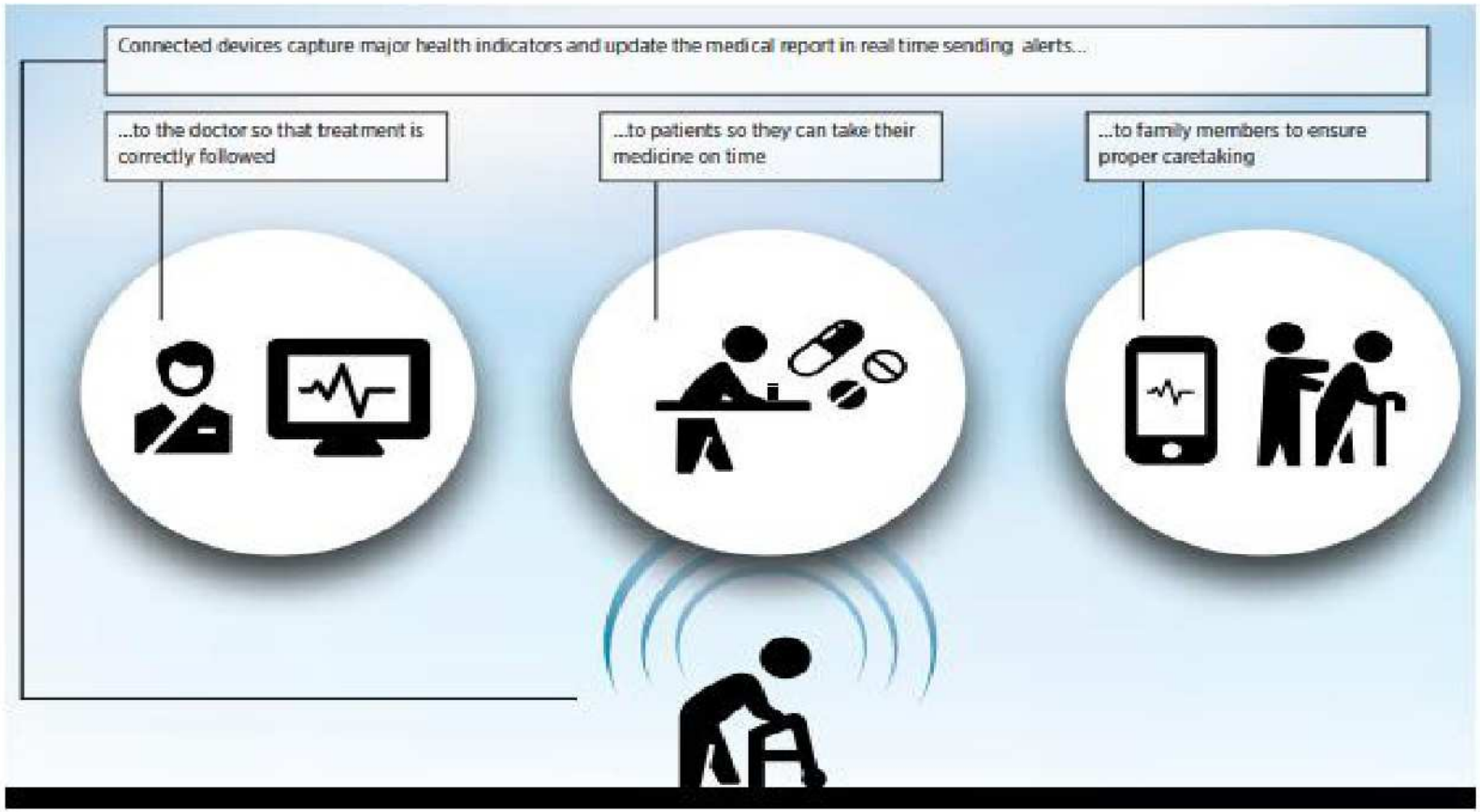
- The task of irrigation can be automated with the help of IoT.
- A set of sensors such as light, humidity, temperature can be used to continuously monitor the field conditions



IoT Application- Smart Healthcare Application

- Smartwatches and fitness devices have changed the frequency of health monitoring.
- People can monitor their own health at regular intervals.
- Not only this, now if a patient is coming to the hospital by ambulance, by the time he or she reaches the hospital his health report is diagnosed by doctors and the hospital quickly starts the treatment.
- The data gathered from multiple healthcare applications are now collected and used to analyze different disease and find its cure.
- Hospitals often use IoT systems to complete tasks such as inventory management, for both pharmaceuticals and medical instruments

Example IoT health applications


Connected devices capture major health indicators and update the medical report in real time sending alerts...
...to the doctor so that treatment is correctly followed
...to patients so they can take their medicine on time
...to family members to ensure proper caretaking

IoT Application- Smart Healthcare Application Cont'd...

- Wearable electronic devices are small devices worn on the head, neck, arms, torso, and feet.
- Current smart wearable devices include:
  - Head - Helmets, glasses
  - Neck - Jewelry, collars
  - Arm - Watches, wristbands, rings
  - Torso - Clothing, backpacks
  - Feet - Socks, shoes
- Wearable devices are also used for public safety
  - Improving first responders' response times during emergencies by providing optimized routes to a location or by tracking construction workers' or firefighters' vital signs at life-threatening sites

IoT Application- Smart Healthcare Application Cont'd...

IoT Application- Smart Education Application

- IoT provides education aids which help in filling the gaps in the education industry.
- It not only improves the quality of education but also optimizes the cost and improves the management by taking into consideration students response and performance.

IoT Application- Air and Water Pollution, Hazards etc.

- Through various sensors, we can detect the pollution in the air and water by frequent sampling.
- This helps in preventing substantial contamination and related disasters
- The Internet of Things platform can be used to accumulate data related to a specific geographic location using remote monitoring tools and perform analytics so that early warnings of a disaster can be found out.

IoT Application- Air and Water Pollution, Hazards

IoT Tools and Application Development Platforms

- **IoT Platform**:
  - IoT platform is an essential component of a huge IoT ecosystem that supports and connects all components within the system.
  - It helps to facilitate device management, handle hardware/software communication protocols, collect/analyze data, enhance data flow and functionality of smart applications
- The overall **IoT system includes**
  - Hardware (devices and sensors)
  - Connectivity through a router, gateway, wi-fi, satellite, Ethernet, etc.
  - Software
  - User interface

IoT Tools and Application Development Platforms

- Cloud hosting has become a wide-spread and generally appreciated method of developing and running various technology solutions,
- IoT, directly depending on Internet, definitely benefits from all the advantages of cloud computing
- Special cloud-based IoT platforms support the Internet-based functions of the application-running, maintenance, analytics, data storage, and security measures.

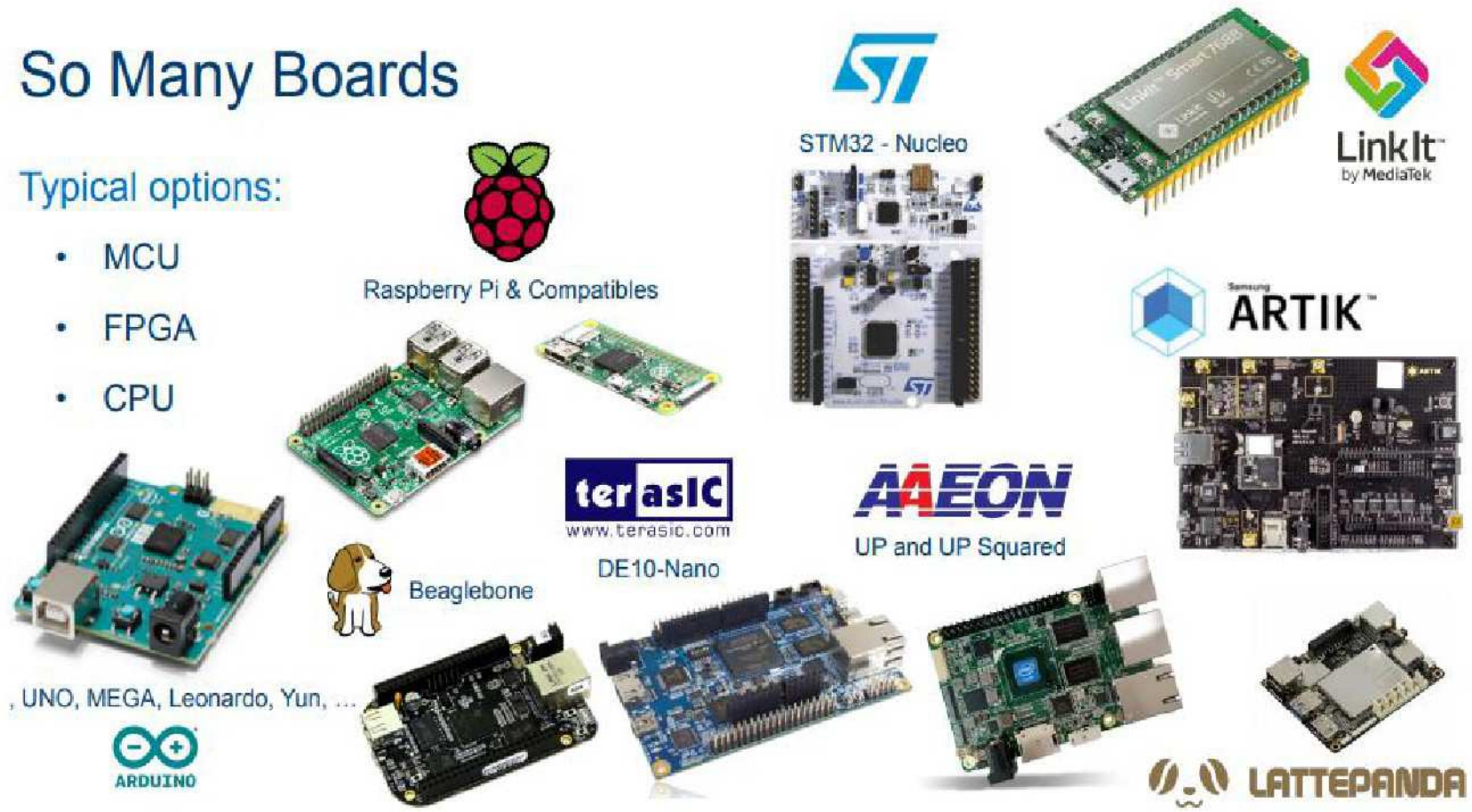
IoT Tools and Application Development Platforms

- Below are some Cloud IoT platforms
  - Google Cloud IoT
  - Microsoft Azure IoT Suite
  - SAP
  - Salesforce IoT
  - Oracle Internet of Things
  - Cisco IoT Cloud Connect
  - Bosch IoT Suite
  - IBM Watson Internet of Things
  - ThingWorx IoT Platform
  - Huawei Cloud Core

IoT Tools and Application Development Platforms

- ## IoT Development Platforms
  - Top-class IoT development tools that can be employed by both developers and for all those who wish to pursue IoT include
    - Tessel 2
    - Eclipse IoT
    - Arduino
    - PlatformIO
    - Kimono Create
    - IBM Watson
    - Raspbian (**Raspberry Pi**)
    - OpenSCADA
    - Node-RED
    - Device Hive

IoT hardware platforms - So many IoT Chips



Chapter 4 - Summary

- In this chapter we have learnt
  - What IoT is and how it emerged as a Technology
  - How IoT works
  - The architectures for IoT(Devices, Network, Communications etc.)
  - The common application areas of IoT in real-life
  - The IoT development and Deployment Platforms